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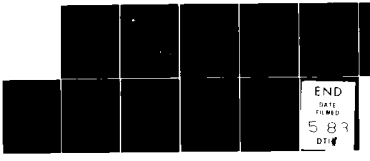

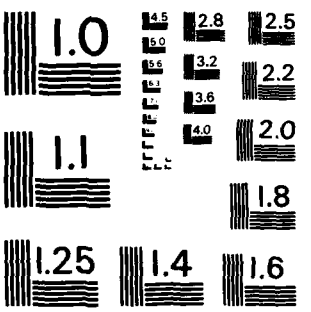

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AUTOMATED DENTAL EPIDEMIOLOGY SYSTEM: I. PRELIMINARY INVESTIGATION AND LITERATURE REVIEW

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AUTOMATED DENTAL EPIDEMIOLOGY SYSTEM: I. PRELIMINARY INVESTIGATION AND LITERATURE REVIEW

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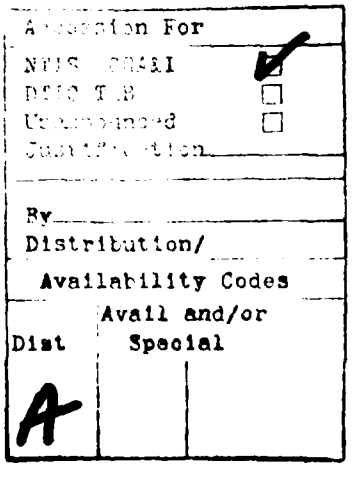

BACKGROUND

The impact of dental emergencies continues to be a pressing problem on operational readiness and mission performance of military forces. Army experience in Vietnam indicated that one person in eight was likely to develop a dental emergency during his tour of duty (1). In previous studies, Navy personnel aboard Fleet Ballistic Missile (FBM) Submarines have been shown to develop an average of three dental emergencies per crew per patrol (2,3). In times when highly trained, specialized and technically skilled personnel are at a premium, a sudden unexpected absence due to dental emergency can critically degrade mission performance and reduce operational readiness.

During the period from 1969 to 1981 various studies have reported the annual dental emergency rates among Army personnel to be between 140 and 234 per thousand (1,4-6). These rates are reported for personnel in a combat theater or during field exercises and usually within relatively easy access to dental treatment. Ludwick et al., noted a slightly higher rate for Navy and Marine Corps personnel during 1969-70; 157 to 210 annual dental emergencies per thousand serving in Vietnam, versus 240 per thousand annual dental emergencies for non-Vietnam personnel (7). Most of these personnel had access to dental treatment comparable to that described in the Army studies.

Sea service, however, is characterized by long periods of isolated duty, frequently in the absence of readily available dental care. Slightly over ten percent of Navy Dental Corps officers served aboard 59 of our 511 ship force in 1982 (8). Of the total Navy and Marine Corps patient population served in 1982, approximately 52 percent were shore-based, with 22 percent onboard ships having one to five dental officers and 26 percent serving on ships without onboard dental professionals (9). Of the shore-based personnel, many served in isolated small detachments where access to dental care was limited.

In 1967, Shiller reported dental emergency data for FBM submarine crews. From this data an annual rate of 130 dental emergencies per thousand personnel is calculated for a patient population, most of whom were in dental class I or II prior to their patrols (2). Shiller noted the mission impact to be an average of 2.79 emergencies per FBM submarine patrol. This rate is comparable to that reported by Nielsen in 1963, of 95 dental emergencies in 32 FBM submarine patrols (3).

Leonard reported that an oiler on extended deployment in the Indian Ocean during 1980 experienced 76 dental emergencies in a crew of slightly over 300 personnel. Of these emergencies, 15 crew members required evacuation, thus being lost to ship operations for an extended period of time (10). This data translates to an annual emergency rate of over 250 per thousand. The Dental Management Information System (DENMIS) System Decision Paper cites the Head, Contingency Planning, Dental Division, as providing three-month dental emergency data for Indian Ocean forces deployed in 1981 (11). Of that force, a daily dental emergency rate of 2.3 persons per thousand was projected. For comparison purposes, this rate is equivalent to an annual rate of 839 per thousand. Evacuation times ranged from one to 21 days for a mean of 5.3 days lost from duty. Contingency Planning, Dental Division further estimates that under similar conditions a ship having a 1000 man crew could expect to lose 60 man-days per week due to dental emergencies, and a naval force of 60,000 personnel could experience 12,000 dental emergencies, of which 35 percent (4200 personnel) would require evacuation to dental treatment facilites.

Although some information exists relating to mission degradation due to dental emergencies, the Navy currently has no information concerning the numbers of deployed personnel whose dental conditions are capable of compromising mission effectiveness. What information as exists, often is statistically incomplete, anecdotal in nature and does not readily lend itself to use in a predictive mode. Specific information concerning the dental needs for this population and its component priority groups must be arduously gleaned through manual review of individual dental records and treatment logs. Emergency data developed by the Army or Air Force often is inapplicable to the Navy, owing to the high portion of naval personnel serving for comparatively long periods isolated from convenient dental care. Experience has shown that to develop such information, considerable effort is required and when obtained, the results are outdated, often by several years.

Dental epidemiology studies as currently conducted in the Navy are manual efforts which use automatic data processing to analyze experimental data, usually via a custom designed protocol (12). These studies are highly labor intensive for relatively small amounts of information developed. They rely upon external sources, principally clinicians in the field to gather source documents and information. This is a tedious task of secondary importance to treatment delivery and detracts from available treatment time. Despite persistent follow-up efforts, much needed source data is lost with missing patient records, lack of patient cooperation for recall examination, postal difficulties, or clinician inavailability to respond. As received, raw data requires considerable effort to extract, compile and prepare for computerized analysis.

Patients and clinicians are vulnerable to the Hawthorne Effects where behavioral distortion occurs when persons know they are objects of or participants in a study (13,14). Thus patients and clinicians who are aware of the existence of a study, will attempt to perform to criteria they believe expected or desired by the observers. This effect has been recently observed in a study on dental emergencies conducted at the Naval Dental Research Institute (15). This behavior, coupled with a lack of standardization, an incomplete understanding of criteria, and differences in professional opinion yields increased error rates and observation inconsistencies that greatly reduce study reliability.

Dictates of economy require the use of relatively small subject samples. Data thus developed applies only to the group from which the sample was taken (e.g., submariners). The sample may not accurately describe the Navy population as a whole. Such studies yield a "normative base" rather than a "needs base" to assess treatment needs (16-18). Similar difficulty in assessing the Dental Information Retrieval System (DIRS) treatment required information is observed. The DIRS uses form NAVMED 6600/7 to gather and evaluate treatment required information by sampling personnel who respond to dental recall at various dental clinics (19). Such uses of the information produced by this sampling technique is not without hazard for considerable error. The wide diversity of oral disease levels among military occupational groups and the fact that the population sampled represents only those personnel seeking treatment mitigates against an accurate assessment of the total population.

Dental epidemiology is essential to understand the natural history of oral diseases for development of an effective methodology to prevent dental emergencies. Long-term dental epidemiology studies also are useful to clinicians seeking to improve professional service and treatment techniques. Such studies on a large

population offer great potential benefits in controlled evaluations of dental materials and restorative techniques. Additionally, a comprehensive epidemiology service can provide valuable management information for Dental Corps strategic planning and for operational planning on the regional level. Within the 750,000 person Navy and Marine Corps population a comprehensive dental epidemiology program is required to provide an in-depth understanding of the composition and distribution of dental disease, the long-term effects of specific dental treatments, and the relative merit of various dental materials and devices. Furthermore, the data produced by such a dental epidemiology system is the logical information source for a comprehensive military dental management information system.

Historical Perspectives

The evolution of information processing in dentistry has an extensive history in the civilian and military communities. Dental condition and oral health status have been recorded on individual records with a variety of format, description, coding and pictorial technique (20-26). Dental information handling applications have evolved concurrently with advances in automatic data processing (ADP) technology. Dental data processing applications, often relating to employment of a specific ADP tool or method, have been described in the literature (27-38). Frequent references to civilian dental computer applications appear in both dental trade journals and in the professional literature (30,31,34,39-46). Most dental ADP applications of significant impact on military dentistry are of civilian origin.

In 1948 Klein and Kramer reported the use of a card-based computerized system to record the results of dental examination (27). Though automated, the system used pre-computer technology requiring Hollerith cards with numeric punches corresponding to ten criteria for deciduous and permanent teeth. With the introduction of electronic computer technology, a ready application to the statistical evaluation of epidemiologic data was found. By 1968 Carlos noted that numerous prior automatic data processing applications to dental epidemiology had extensively employed optical character reading as a replacement for mark-sense equipment (37).

Marthaler et al., cite the evolution of dental data evaluation from small operations to central data processing in large computer centers (47). World Health Organization offers a two-month turn-around for dental epidemiology data on patient populations of less than 1000 individuals, with a longer waiting time for larger populations (47,48). In 1974 the National Institute of Dental Research, Bethesda, Maryland, developed an oral epidemiology data processing program. Since that time this program has nearly doubled in size and now incorporates statistical methods to yield DMFS, DMFT, DFS, etc., information (47).

Wooten described a basic philosophy to analyze patient pools by computer at Virginia Commonwealth University (49). Patient groups were found to be easily and quickly compared and evaluated for clinical administrative purposes. Noted were increased system efficiency and the ability to use pre-existing statistical software after patient population files were developed.

Pieper et al., described the use of a microcomputer to record dental epidemiologic data (50). The principal advantage of such real-time data entry was found to be the ability to perform data checks and immediately correct errors on-site. Upon completion of data input, the information stored in the microcomputer was transferred to a larger main computer for analysis. Pieper

noted an extremely low error rate for data entry. One dentist examined 141 patients, dictating to two assistants who alternated manual and microcomputer data transcription. In 3100 caries findings, there were 60 errors entered, of which 58 occurred as manual data transcription charting mistakes.

Logical errors by the dentist (e.g., indicating caries on a missing tooth) were found by Pieper to occur at the rate of one per ten patients; all such errors were detected by the computer. Pieper notes in a communication from Marthaler, that such logical errors remain at one to two percent despite considerable effort to develop specially trained assistants over several years. Pieper also noted that direct data entry into the microcomputer was nine times faster than manual data recording onto dental charts (50).

In 1965, an extensive dental data reporting system was developed for use by the Indian Health Service (51). This comprehensive system supported dental service to a 403,000 person, relatively stable population. Per-person oral health and orthodontic indices were developed, and clinic workload requirements were derived. From the examination results and information on treatment provided, it was possible to intelligently develop timely plans for resource adjustment and to evaluate staff service and productivity. The degree of treatment comprehensiveness was determined, and provision for independent clinical research and administrative functions were programmed into the system.

Mecklenberg, in describing the Indian Health Service System, noted that the principal result was an increase in productivity. Improved planning logic was made possible by a qualitative increase in available management information. A decrease in paperwork load demanded of the clinic staff translated into an increase in the amount of treatment provided. Like Pieper, Mecklenberg found that the required information handling time decreased by 90 percent, error rates plummeted and there was timely availability of needed information. In terms of increased operational efficiency and productivity, the expense of research and development was recouped in eight months of operation (51).

Similar to the Indian Health Service dental system, Lewis et al., describe an optical character reader (OCR) based system to provide ongoing or prospective studies in rural Tennessee (52). This system employed an IBM 1287 or 1288 Optical Page Reader to capture dental epidemiology and service-provided information. Optical character recognition was selected for operations in 1970 after comparison with key-punch and mark-sense forms. Forms prepared by individual treatment providers were to be collected at monthly intervals, reviewed for accuracy and neatness, and then read via OCR into a computerized system. The system then checked for errors, rejecting those forms on which errors were detected and listing errors on a printout. Input data was then stored on magnetic tape for subsequent epidemiology and administrative data processing.

Leverett et al., describe a data processing system developed at the Eastman Dental Center (53). This system employed remote data entry in support of a three-chair mobile dental clinic. Concerned initially with a study of pit and fissure sealants, the program expanded to include administrative functions of productivity description and evaluation as a measure to determine service cost effectiveness. Information relating to patient data, treatment needs, and treatment provided was captured using data sheets and custom-developed IBM Port-a-Punch™ cards. By using remote data capture with central processing, system costs were kept within a modest ADP budget.

The Omnibus Dental Online Treatment and Information Control System, "ODONTICS", was developed at West Virginia University School of Dentistry to provide multi-functional information management in a large clinical setting (54,55). ODONTICS, as described, is a transaction-driven, i.e., management information system or MIS, database system written in the COBOL data processing language. Database maintenance operations (data entry, manipulation and deletion) are conducted online by administrative and clerical personnel using terminals located in various clinical areas. Printed output is available through several printers located throughout the dental school.

Seven transactions dealing with patient management, from patient screening to treatment progress evaluation, a student evaluation, personnel record, clinic operations and administrative support, and school administrative support comprise the functions of this comprehensive system. Graham et al., indicate that ODONTICS has fulfilled its principal goals; to enhance quality assurance in a departmentalized, comprehensive-care, clinical teaching environment. In addition, ODONTICS appears promising in various areas of administrative operations and in educational/institutional research. As a demonstration project, ODONTICS proved that a transaction-driven database system (a MIS) is viable in the management of large clinical facilities (54,55).

Automatic data processing applications in military dentistry have evolved coincident to similar events in the civilian sector. Longton, Rovelstad and Schilsky developed a mark-sense, optical reading procedure at NDRI to detail patient oral health status (35). This methodology followed closely that by Lobene and earlier work by Shiene and others (29,33). Bognore, Hoerman and Mayhew developed an automated dental history interviewing method after similar developments in the civilian medical community (56). Cohen and Cecil developed a mark-sense multi-card optical scan technique to record and enter dental examination data for computerized epidemiologic processing (57). Military dental epidemiology has largely been limited to studying dental health status and the nature of dental emergencies in recruit training and field training populations (1,5,6,58-60). These studies were confined to relatively captive population samples since obtaining equivalent source data from deployed operational units on a regular basis was essentially impossible.

To assist in the gathering and processing of both management and epidemiology information, the Navy Dental Corps implemented the Dental Information Retrieval System (DIRS) in 1979 (61,62). Principally, the DIRS represents an automated refinement of the preceding management data gathering technique employing the DD-477 Dental Service Report (63). The DIRS employs a centralized data processing approach where information is routinely submitted from dental facilities via the mark-sense form NAVMED 6600/7. Primary intent is to obtain information on clinic productivity. Epidemiologic data through DIRS is obtained by sampling those personnel voluntarily appearing at the dental facility (61).

Because DIRS performance falls short of expectation in Dental Corps strategic and operational management and due to its limited utility in dental epidemiology, alternate solutions have recently been sought (11,64). The Dental Management Information System (DENMIS) proposal represents a considerable conceptual advance over DIRS in that it seeks to increase the efficiency of clinical operations using current technology, while meeting objectives which enhance Dental Corps mission accomplishment (11). Identical goals have been established for all Armed Forces Dental Corps as part of TRIMIS, the Tri-Service Medical Information System (65-69).

Data processing applications to naval dental service has not been confined to large, centrally directed administrative efforts such as DIRS, DENMIS or TRIMIS. On an operational level, command and staff personnel of several Navy Dental Corps regional centers and branch clinics have independently sought specific local applications. Typically this has been an optimization of the dental recall aspect of the Navy Preventive Dentistry Program. This program includes an annual dental examination, topical fluoride application and oral hygiene instruction for all active duty Navy and Marine Corps personnel (70). In response, dental regions and branch clinics have developed dental recall programs, usually as a manual operation. Automation has enabled optimization of the dental recall program in several facilities.

Caron, Wilkie and Loizeaux described an automated dental recall system at the Naval Regional Dental Center, Pearl Harbor (71). This system automated dental records management for approximately 25,000 patients using equipment at the Data Processing Service Center Pacific, Pearl Harbor. As designed, this application monitors patient files for: dental examination and fluoride treatment status, current dental classification, and identification of individual treatment needs by specialty area. Output of the system includes a list identifying personnel for whom annual preventive dental procedures are required. These personnel are selected based upon elapsed time from previous preventive dental treatment.

The Naval Regional Dental Center, Charleston, has applied a similar automated preventive dentistry program to successfully serve in the fleet environment (72). In this approach, dental records information is maintained on all patients in a local computerized data bank. System output includes dental recall notices and follow-up messages, and estimates of dental treatment requirements for individual personnel. These estimates provide to operational unit managers information regarding the dental class and time estimates to accomplish needed treatment for individual crew members. Crew composition by dental class percentages and other information provide an indication of unit dental readiness.

Alternate approaches to automated dental recall include personnel selection based upon birth month or SSN terminal digit sequences. Each of these approaches has evident advantages. Birth month dental recall is easily remembered by personnel. It is well suited for manual dental recall systems and automated versions of manual systems. Terminal digit selection correlates well with the current records filing system (73). Automated dental recall based upon terminal digit sequencing has proved to be expeditious and an economical advance over cumbersome, time-consuming manual recall operations (74). Such applications have been developed for use at the Naval Regional Dental Center, Great Lakes, and the Branch Dental Clinic, Rota, Spain, among others. This approach is particularly more efficient than birth month or elapsed time selection since it streamlines the extraction of dental records from clinic central files. In this approach, patient information, including terminal digit selection keys and personnel activity location, is extracted from base locator or military payroll files. Such basic programs offer the significant advantage that huge volumes of patient information are extracted from existing, verified electronic files. To develop an equivalent custom dental data bank would require extensive entry of identical information obtained from review of those dental records maintained in clinic facilities or accessible by clinic personnel. This approach also is more easily incorporated into an extensive, interactive patient management system.

An integrated patient management system was developed at Rota, Spain and demonstrated at the 1981 USAREUR and 7th Army Dental Training Conference (74,75).

In this microcomputer based system, patient and dental procedural files were established to record and maintain clinical information. As each patient received treatment, pertinent information was entered into a chronology working file and used to update the patient and procedural files. This information was printed out directly onto the patient's SF-603 treatment record and automatically processed for procedural accounting information. Provision for dental recall by terminal digit sequencing or birth month was included, as was a dental profile of operational units. Provision was also made for program modules including medical history precautions, supply consumption rate determinations, and craniofacial analysis. This system was used as a pattern to develop a proposal to automate the Rota dental clinic through interactive terminal access to an IBM 4331 computer at the Data Processing Service Center, Rota (76).

PRELIMINARY INVESTIGATION

Methods

A preliminary investigation was conducted at the Naval Dental Research Institute (NDRI) and the Naval Regional Dental Center (NRDC), Great Lakes, using conventional systems analysis techniques (77-80). The initial task was to gain an understanding of the nature of those problems previously stated. Problem size and scope were determined to establish boundaries for the current study. Alternative solutions, their benefits and approximate cost estimates were determined for both NDRI and NRDC, Great Lakes.

Applications of dental epidemiology to both clinical management and professional aspects of military dentistry were determined. Key personnel were identified for the conduct of formal and informal interviews. Direct observations were made to augment impressions and previous experience, and to gain an understanding of clinic operations from a managerial perspective. Documents, where pertinent to this understanding, were obtained and analyzed. All aspects of this preliminary investigation were assembled into a continually updated file for subsequent analysis.

Results

Initial investigation identified two general problem areas. There are difficulties experienced in the conduct of formal epidemiology studies, principally as related to rigorous, formal analysis of the impact of dental treatment and dental emergencies on military operations. Secondly, on the clinical level, information scarcity and compilation problems have impeded optimum management of and professional development in military dentistry.

There are difficulties to routinely obtaining comprehensive emergency and treatment information at the clinical level. Criteria to define the "dental emergency" is not uniform throughout the Dental Corps, often being subject to interpretation by individual professional opinion. Difficulties have been experienced in information transmission from data collection site to analysis point. Information developed by epidemiology research often does not reach potential users, such as Dental Corps administrators and the various regional and clinical managers, with sufficient speed to permit timely response. Additionally, there appears to be no usage recommendations nor guidelines for the often complex information developed by epidemiology studies.

A major problem area found in both this and previous studies dealing with Dental Corps data automation deals directly with the dental treatment provider. There is excessive time spent preparing source documents for procedural accounting, time management evaluation, etc., to the detriment of available treatment delivery time. Treatment provided source documents routinely prepared are duplicate records which, for audit purposes, are not guaranteed to contain information identical to that noted on the SF-603 treatment record.

For certain dental materials and treatment techniques there are areas of incomplete information potentially useful as guidelines for professional selection of treatment appropriate in the military environment. This chronic problem is one of the principal motivators in the civilian sector for research directed toward improvement of dental materials, devices and techniques for the enhancement of treatment efficacy. Without sufficient longitudinal information on materials performance, the profession cannot sensibly evaluate the long-term treatment efficacy of these materials.

Several areas where a lack of information available to clinic managers detracts from maximal efficiency were identified. On the local clinical level, there is considerable effort required to obtain and compile adequate administrative information. Consequently, there often is incomplete information concerning the effect of treatment received at clinics supporting recruit and service school training on overall dental health of those personnel. This restricts the effectiveness of the service planning effort, especially in the allocation of resources to priority treatment groups and in minimizing the incidence of future dental emergencies. From a managerial view, currently available information relating to professional productivity and efficiency is neither sufficiently timely nor extensive enough to permit optimal local control.

Regional administration and clinical management were found to be highly receptive to innovative efforts directed toward enhancement of their operations. Several specific problems, to be detailed in a subsequent systems analysis report, were targeted by NRDC, Great Lakes, personnel for priority solution. There was near universal agreement among all personnel contacted concerning the inadequacy of DIRS for regional and clinical management. There also was skepticism regarding the prognosis of any attempt at an automated dental information system which did not have extensive interaction with local clinical users during the planning, design and development stages.

Conclusion

Initial investigation indicates two potential solutions to the problems cited: a manual approach which increases the number of personnel assigned to information processing tasks in the clinics, and an automated approach using data processing technology to augment clinical management functions. Both of these solutions can potentially enhance clinical management and regional administration through optimal development and utilization of dental epidemiology information. The manual alternative, however, would require considerably more personnel to reach a comparable level of proficiency as compared to the automated alternative.

Increasing the manual effort dedicated to information processing at the NRDC, Great Lakes, facilities would require an additional seven to ten personnel and the expense of additional forms and business machine calculator equipment. Simplifying

the clerical procedures involved in this alternative would be a difficult task, with a likelihood of only marginal success. Using this approach, reduction of the clerical workload experienced by clinical personnel would be unlikely. This approach would probably not produce an adequate solution at reasonable cost.

An automated information handling approach would, among numerous additional benefits, solve those problems previously cited in a highly cost-effective manner. Current technology is capable of supporting potential automated solutions, with little or no difficulty in personnel training nor increase in number of personnel required to operate the equipment. Little disruption in clinic routine and operational procedures is expected with judicious implementation of automation.

A phased addition of equipment and automated information handling procedures to NRDC facilities over a period of one to three years appears optimal. For the automated approach, expected costs appear to be in the range of $10,000 one-time expense and $15,000 to $25,000 recurring expenses, depending on specific data processing techniques selected. Probable recurrent cost for the additional personnel required to achieve equivalent performance by manual methods is conservatively estimated at $75,000. Conservative projection indicates an annual cost saving of $50,000 can be expected with full implementation of an automated dental epidemiology system.

This initial investigation concluded that Dental Corps management and professional requirements for timely and useful epidemiology information could be easily satisfied by an automated data processing approach. Potential for such enhancement exists at all levels of Dental Corps management. An automated dental epidemiology system offers the capability to enhance the efficiency, sophistication and utilization of military oral epidemiology. By integrating an automated dental epidemiology system with a dental management information system such as TRIMIS or DENMIS, considerably enhanced utility of either MIS could be achieved with little or no increased cost. Beyond system development and prove-in, an automated dental epidemiology system serving the Naval Regional Dental Center at Great Lakes could function as reliable test-bed for proving-in equipment specification concepts as proposed for systems like DENMIS.

A computerized system could eliminate the demands for data acquisition and interpretation by clinicians, automatically capture and analyze data, and routinely produce timely reports which comprehensively describe the dental health of the entire Navy and Marine Corps population. The Navy Preventive Dentistry Program could be enhanced by an integrated, interactive computerized recall program. Dental status reports, portraying the dental readiness of individual operational units would be a valuable management tool for mission and deployment planning. The net result of an automated dental epidemiology operation would likely be the reduction of dental emergencies in the operational forces, and hence, a reduction in the incidence of compromised and aborted missions. Additionally there would be a great potential for enhanced service planning at all levels of the Dental Corps and a Navy-wide impetus to achieve and maintain the highest levels of dental service utilization.

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Dental emergencies among naval personnel can adversely affect military operations. The Navy currently has no routine availability of timely, comprehensive dental epidemiology information. Such information is essential for service planning, professional service and quality assurance enhancement, and prevention of dental emergencies in the operational forces. A preliminary investigation concluded that an automated dental epidemiology system can potentially offer considerable benefit to the Dental Corps. An extensive review of civilian and military developments in dental automation was conducted

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